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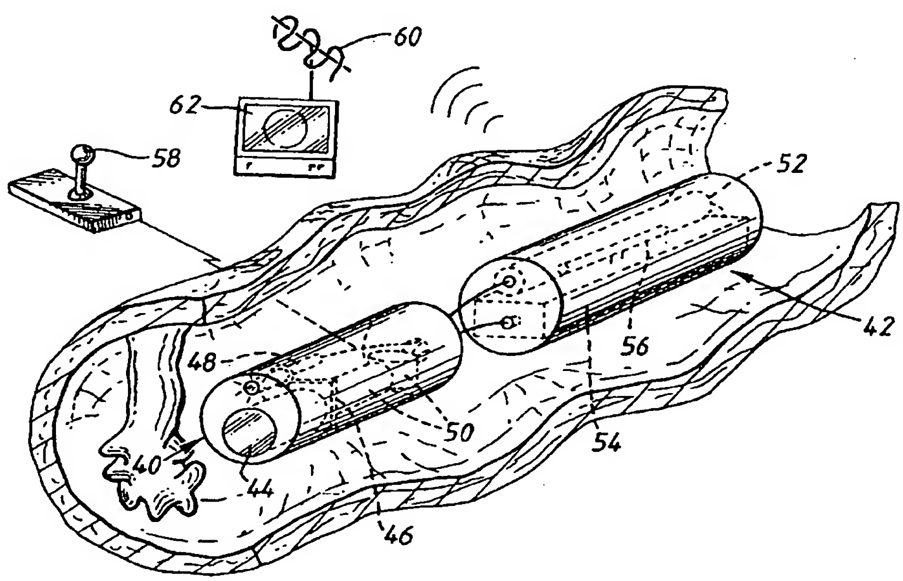

(57) Abstract

An apparatus is provided for giving an image of a location within a human or animal body. This comprises an imaging device having its own means of propulsion and movable within the body without the assistance of pushing from the exterior of the body, transmission means for wireless transmission of an image from the imaging device to the exterior of the body, and means for receiving the image so transmitted. In an alternative form, the propulsion means is omitted and the imaging device is attached, for example by sewing, within the body. In another alternative the imaging device is carried by an endoscope.

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IMAGING APPARATUS

This invention relates to an apparatus for use in providing an image of a location within a human or animal body.

Conventionally, such images are produced in two ways. Firstly, the body can be subjected to external electromagnetic radiation, as happens, for example, in X-ray imaging and magnetic resonance imaging. The apparatus required for this is expensive, whatever the particular technique which is used, and in the case of some techniques (for example magnetic resonance imaging) is very expensive. There are also limitations on what can be imaged in this way, and some techniques, for example X-ray imaging, can be damaging to the subject being imaged. Secondly, images of some locations, for example the interior of the human gut, can be produced by inserting an endoscope which has an optical channel through which light is directed from the exterior of the body to the site, at the distal end of the endoscope, which is to be viewed, with a proportion of that light passing back up through the optical channel to be viewed at the proximal end.

In contrast, and in accordance with a first aspect of the present invention, there is provided an apparatus for use in providing an image of a location within a human or animal body, which comprises an imaging device locatable within the body and operable to produce an image of the location in the form of an electrical signal, means for wireless transmission of the signal to the exterior of the body, and a receiver disposed externally of the body for recording the transmitted signal. Preferably, the transmission means is a microwave transmitter and the receiver is a microwave receiver. The receiver provides a signal to a monitor to enable it to be viewed. If desired, the signal can be recorded, either simultaneously with its being viewed or for subsequent viewing.

Mention should be made of a in the prior art (see EP-A-667115) for a swallowable capsule which has a video camera and a radio frequency transmitter. As far as the present applicants are aware this proposal has never been commercially implemented. It should be noted that the capsule is entirely at the mercy of peristaltic motion within the gut, and is not, therefore, truly locatable, as that term is used herein.

The means for locating the imaging device within the body may resemble a conventional endoscope, and may thus comprise an elongate member which has the imaging device at its distal end and which, though flexible, has sufficient stiffness to enable its distal end to be pushed to the desired location, after introduction through the mouth or anus of the subject. However, as will be explained further below, the locating device could be quite different in character.

Although endoscopes are usable for obtaining images from within the human or animal body, either by the optical method of the prior art, or by the aspect of the present invention described above, they have a number of significant disadvantages. One of these is that they can cause considerable discomfort to the patient. The flexible member of an endoscope is of substantial diameter (usually about 1 cm) and the tube is quite stiff, and the patient experiences a very disagreeable sensation while it is in place and, even more, while it is being inserted. Furthermore, only about 30% of the length of the gastrointestinal tract can be reached by an endoscope. The remaining 70%, namely the small bowel and the right side of the colon, cannot be reached by a conventional endoscope.

In accordance with a further aspect of the present invention, there is provided an apparatus for use in providing an image of a location within a human or animal body, which comprises an imaging device having its own means of propulsion and movable within the body without the assistance of pushing from the exterior of the body, transmission means for wireless transmission of an image from the imaging device to the exterior of the body, and means for receiving the image so transmitted. As with the first aspect of the invention, transmission means is preferably a microwave transmitter, and the receiving means comprises a microwave receiver.

This aspect of the invention requires a suitable propulsion means, for example for enabling the imaging device to be propelled within the human gut. Such devices are described in the prior art, and some of these will now be mentioned.

Firstly, attention is directed to Fukuda T, Hosokai H, Ohyama H, Hashimoto H, Arai F. "Giant Magnetostrictive Alloy (GMA) applications to micro mobile robot as a micro actuator without power supply cables". IEEE, 1991, 210-215. This describes two minute micro robots which required no power supply cables. So-called giant magnetostrictive alloy (GMA) was used for the micro actuators in the robots,

which were then powered by externally supplied magnetic fields. The mechanisms for motion were based on inch-worm type mechanisms. The motion was controlled by the regulated motion of an outer electro-magnetic coil, with the robot moving by following the outer coil. Since the devices described by Fukuda et al require no external power supply cables, their design can be used in the context of the present invention to give an imaging device capable of travelling freely through, for example, the human gut, without any connection to the exterior, somewhat in the manner of a miniature submarine.

Another potentially usable means of propulsion for the purposes of the present invention is described in The Japan Robot News, 1991; 10(12): 1. This describes a design developed by Toshiba Corporation and shown in Figure 1 of the accompanying drawings. This is a micro robot whose shape derives from connecting two pieces of rubber tube 2,4, and which can snake through a duct 6 at a speed of 10 mm/min by the force of air pressure. The rubber tubes functioning as the robot body structure are divided into three compartments 8a, 8b, 8c by partitions. The tube is bent by changing the level of air pressure in the compartments through pipes 10a, 10b, 10c, the air pressure in the compartments of tube 4 being changed by corresponding tubes (not shown) and snaking forward moving action is created by slightly staggering the motion of each of the two rubber tubes. By reversing this motion, the robot can go backward. No electricity is used for motion control, which is a major advantage for medical applications.

Another design is described in Guber AE. "Potential of microsystems in medicine." Minimally Invasive Therapy. 1995;4:267-275. The design was described for use in a blood vessel, but in principle is applicable to propulsion along any other tubular cavity, for example the gut. The design is shown in Figure 2 and consists of a catheter 20 that is divided into two parts 20a and 20b. The front and rear part are connected by a telescopic section 20c. To enable the catheter 20 to be supported in the body cavities, two mini-balloons 22a and 22b are applied, one to each of the catheter parts 20a and 20b. The balloons are controlled by a central microvalve system, which inflates and deflates the balloons in a predetermined sequence, to cause them either to grip the adjacent body cavity wall or not to grip them, and also inflates or deflates the telescopic section 20c. The sequence involved

is shown in Figures 2a to 2d. By this means, which is an application of the inch-worm principle, the entire system can move independently through the body cavities. This design, like the Toshiba design just described, and unlike the design of Fukuda et al, requires permanent connection, via an umbilical cord 24, to a point exterior of the body for the purpose of providing fluid pressure. It should be noted, nevertheless, that the connection is not for the purpose of pushing the device along, so the main disadvantages of a conventional endoscope are still avoided.

Attention is also directed to Slatkin AB, Burdick J, Grundfest W. "The development of a robotic endoscope." Proc. of IROS Conference, 1995, which describes a robotic endoscope for gastrointestinal diagnosis and therapy. This is shown in Figure 3 of the accompanying drawings. The endoscope consists of electric wiring 30 for control signals, tubing 32 to connect pneumatic actuators used for propulsion to high/low pressure sources, and a fibre-optical bundle 34 for illumination of the area in front of the robot and its imaging by a video camera 39. The propulsion mechanism uses grippers 36 and extensors 38, which cooperate with one another to move the device along the gastrointestinal tract. This too is a device which is permanently connected to a location exterior of the patient's body. In the context of the description given by Slatkin et al, this was for three reasons, namely to allow pneumatic power to be supplied to the propulsion system, to allow control signals to be supplied to the propulsion system, and to enable light to travel down the fibre-optical bundle for illumination purposes and to travel back up the fibre optical bundle with the image. In the context of the present invention, however, the propulsion system of Slatkin can be used with a permanent connection serving only the first of these three functions. The control signals could, if desired, be provided by electromagnetic signals transmitted wirelessly, and the image from the imaging device is transmitted wirelessly. Further details of the Slatkin et al device can be found in US-A-5337732.

Finally, attention is directed to US-A-4735501 (Ginsburgh et al) which describes a method of propelling a borescope, for example an endoscope, using reaction jets of gas, liquid or other fluid, for example jets of water or other liquid.

As already mentioned, a preferred method of transmitting the image from the imaging device to the exterior of the body is by means of a microwave signal. It has

been found that, provided a suitable frequency is chosen, such a signal can carry the information required in transmitting a colour video signal without suffering unacceptable attenuation in passing through the body tissue which lies in the path of the signal from the transmitter to the receiver.

Given that the bandwidth of a colour video signal is about 8 MHz, the minimum acceptable carrier frequency is of the order of 100 MHz. Accordingly, the carrier frequency used should not be significantly lower than this value. However, a frequency of 100 MHz corresponds to a wavelength of 3 m, which means that if the transmitting antenna is a dipole it will need to have a length of 1.5 m. This is clearly impractical inside, for example, the human body. A dipole antenna is preferable, though not essential, as it gives directional transmission of the signal. Increasing the frequency has the disadvantage of increasing the propagation loss in the body tissue. For example, a frequency of 10 GHz corresponds to a dipole transmitter 15mm in length, which is entirely practical, but the trade off in terms of propagation loss is that whereas the coefficient of attenuation μ_a of a 100 MHz signal by body tissues appears to be typically about 3 cm, the value of μ_a at 10 GHz is of the order of one tenth of that value. If a large receiver is used, so that directional transmission is not important, a frequency of around 100 MHz may be best.

Practice of the invention also has to take account of the fact that only certain microwave frequencies are available for public use. The restrictions vary from time to time and from country to country, and are therefore not discussed further here. It should be added that whatever frequency is chosen it is desirable to avoid frequencies at which there is abnormal absorption, for example, the 2.45 GHz frequency at which microwave energy is absorbed by water.

An embodiment of the present invention is shown schematically in Figure 4. This has a pair of elements 40, 42 for location within the human gut, the elements being connected to one another somewhat in the manner of a string of sausages. The forward element 40 comprises a lens 44, a CCD chip 46 for generating an electrical signal from the optical image produced by the lens, a light source 48 (for example a halogen bulb) and a camera control system 50 for the CCD chip. The rear element 42 comprises a battery 52 which provides power to the components in the forward element, a transmitter 54 and an aerial 56. Also, although not shown, the forward

element would be provided with a propulsion means. The device is controlled by a joystick control 58 located exteriorly of the body. This controls the movement of the elements within the body, and can also be used to turn the system on and off. For example, in order to conserve power it may be desirable to provide power to the light source, CCD chip and CCD camera control only for short periods of time when the device is at the desired location. The signals sent by the aerial with which the rear element is provided are picked up by a receiver 60 located exteriorly of the body, and the resulting image viewed on a monitor 62.

Rather than provide the device with its own power source (in this case a battery) an alternative is to supply power non-invasively through the patient's tissue, for example by ultrasound transmission or inducing electrical power using an external electromagnetic coil. Other forms of power which can be used within the body, in place of a conventional electrical battery, include biological batteries, nuclear batteries and electromechanical systems in which energy from movement of the body (e.g. walking, running, movements of the chest wall, movements of the heart) is converted in electrical energy, similarly to the way in which wrist movements can be used to power watches.

Finally, mention should be made of a further aspect of the invention, according to which the camera and associated components are attached to a tissue wall within the patient, for example by sewing, rather than being mobile. Devices are known in the art for endoscopic sewing, and such a device can be used in this instance. The camera or one of the associated components will then need to be provided with an attachment means, for example a loop, to enable the sewing thread to hold the camera reliably to the tissue.

CLAIMS:

1. An apparatus for use in providing an image of a location within a human or animal body, which comprises an imaging device having its own means of propulsion of pushing from the exterior of the body, transmission means for wireless transmission of an image from the imaging device to the exterior of the body, and means for receiving the image so transmitted.

2. An apparatus according to claim 1, wherein the transmission means is a microwave transmitter, and the receiving means is a microwave receiver.

3. An apparatus according to claim 2, wherein the transmitter means employs a carrier frequency in the range of from of the order of MHz to of the order of 10 GHz.

4. An apparatus according to claims 2 or 3, wherein the transmitter has a dipole aerial.

5. An apparatus according to any preceding claim, further comprising a monitor to enable the received image to be viewed.

6. An apparatus according to any preceding claim, further comprising means for recording for the received image.

7. An apparatus according to any preceding claim, which carries its own power source with it.

8. An apparatus according to any one of claims 1 to 6, which is provided with power via a line to it passing within the body being imaged.

9. An apparatus according to claim 8, wherein the said line comprises an electrical conductor for carrying electrical power.

10. An apparatus according to claim 8 or 9, wherein the said line comprises a fluid line for carrying a fluid under pressure.

11. An apparatus according to any of claims 1 to 6, adapted to be supplied with power non-invasively through the tissue of the human or animal body.

12. An apparatus for use in providing an image of a location within a human or animal body, which comprises an imaging device adapted to be attached to a tissue wall within the said body, transmission means for wireless transmission of an image from the imaging device to the exterior of the body, and means for receiving the image so transmitted.

13. An apparatus according to claim 12, wherein the imaging device is adapted to be attached to said tissue wall by sewing.

14. An apparatus according to claim 12 or 13, further comprising the features of any of claims 2 to 9 and 11.

15. An apparatus for use in providing an image of a location within a human or animal body, which comprises an imaging device locatable within the body and operable to produce an image of the location in the form of an electrical signal, means for wireless transmission of the signal to the exterior of the body, and a receiver disposed externally of the body for recording the transmitted signal.

16. An apparatus according to claim 15, wherein the imaging device is mounted on an endoscope.

17. An apparatus according to claim 16, wherein the imaging device is mounted on the end of the endoscope.

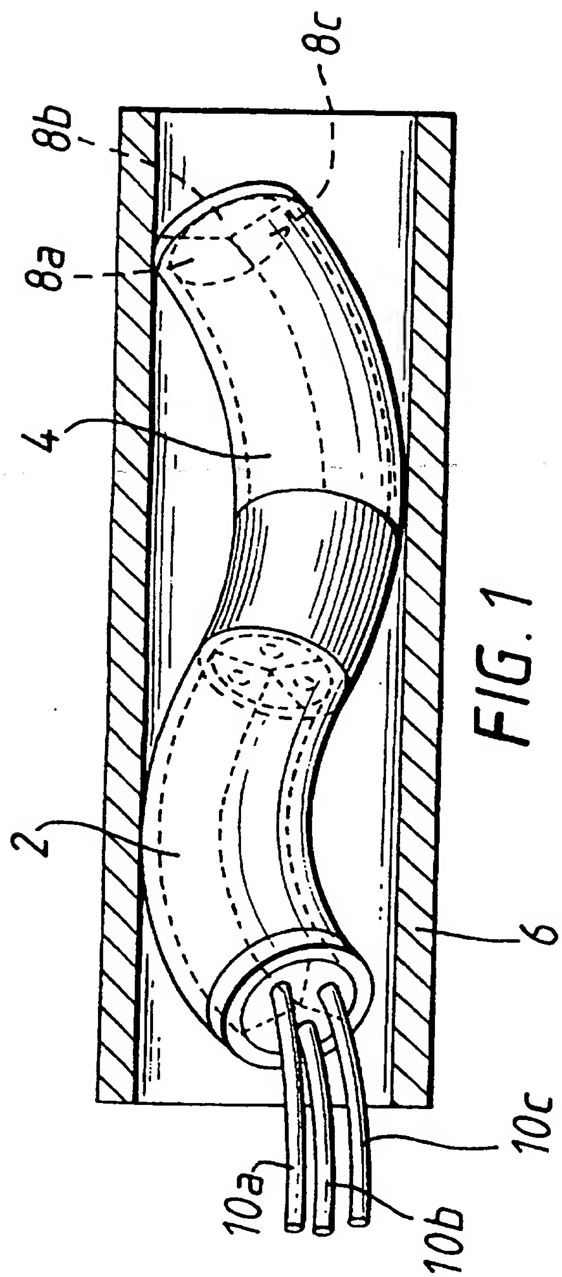


FIG. 1

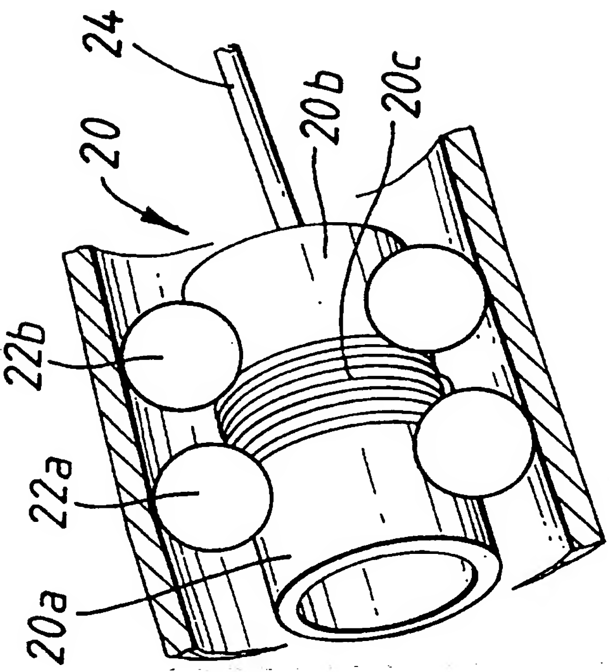


FIG. 2

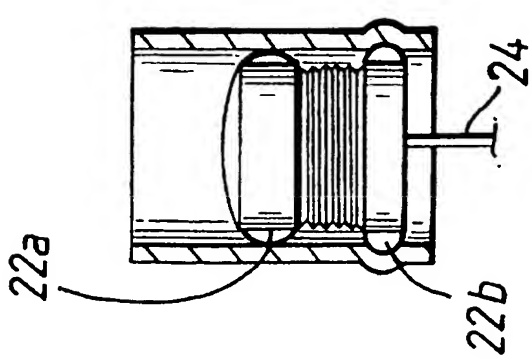


FIG. 2a

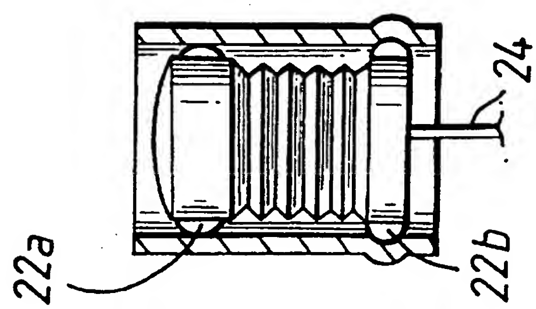


FIG. 2b

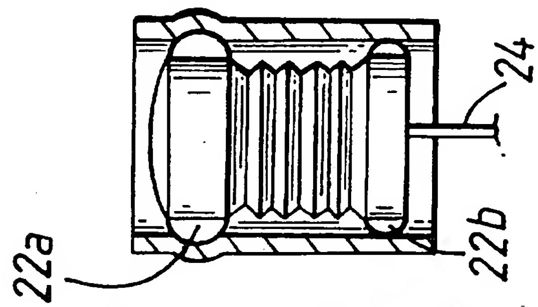


FIG. 2c

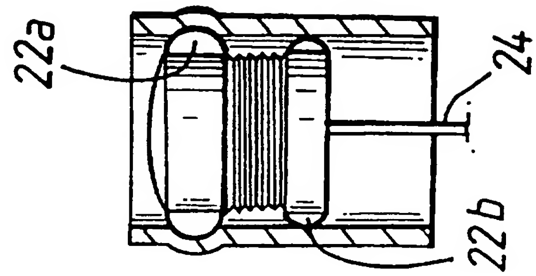


FIG. 2d

FIG. 3

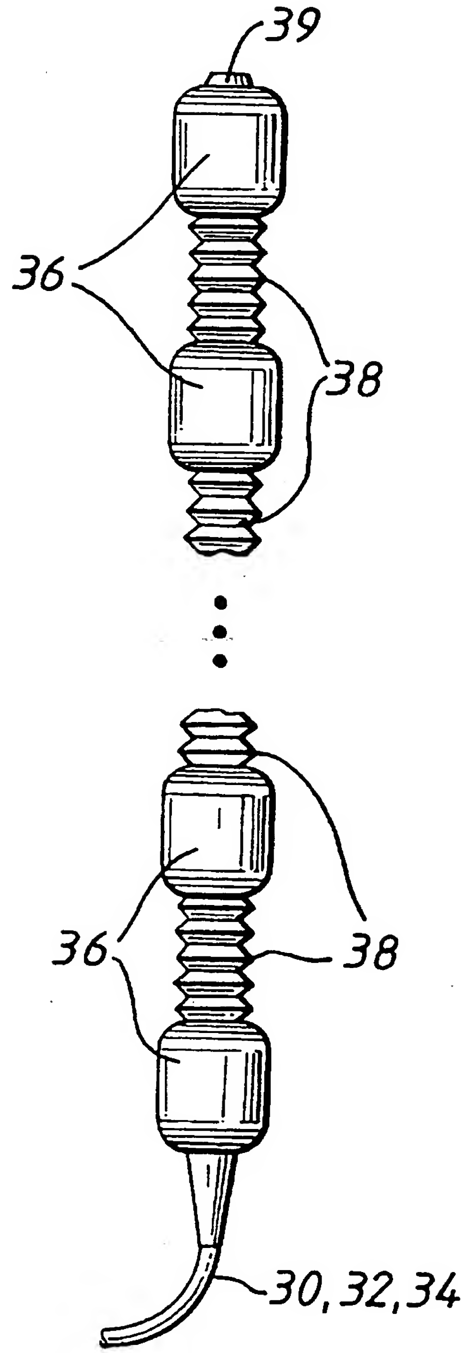
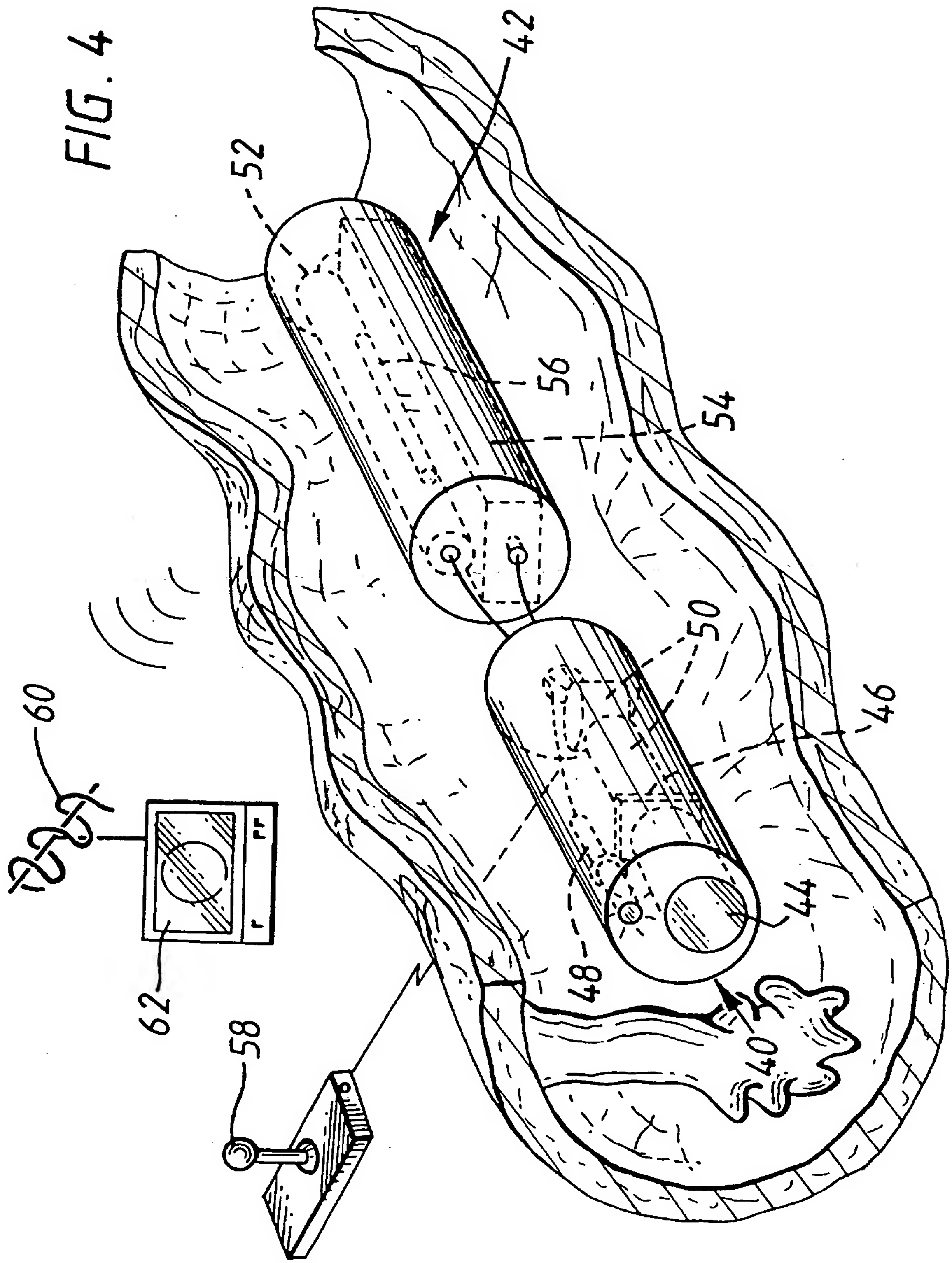


FIG. 4



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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61B1/05

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61B

Documentation searched other than minimumdocumentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 667 115 A (STATE OF ISRAEL) 16 August 1995 cited in the application see column 3, line 37 - column 4, line 38 ---	1-3,5-7
X	EP 0 677 272 A (SIGHTLINE TECHNOLOGIES) 18 October 1995 see the whole document ---	1,5-9
X	US 5 337 732 A (CEDARS-SINAI) 16 August 1994 cited in the application see column 3, line 15 - column 4, line 47 --- -/--	1,5,7, 15-17

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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2

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	FUKUDA & AL: "Giant magnetostrictive alloy (GMA) applications to micro mobile robot as a micro actuator without power supply cables" IEEE, 1991, JAPAN, pages 210-215, XP000295570 cited in the application	1,11
A	SLATKIN & AL: "The development of a robotic endoscope" IEEE, vol. 2, 1995, USA, pages 162-171, XP002053330 cited in the application	1,8-10
X	US 4 109 644 A (KOJIMA) 29 August 1978 see the whole document	12-14

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. onal Application No
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